

REMARKS

Claims 1-6 have been amended. Claim 7 has been withdrawn. New claims 8-14 have been added. Accordingly, claims 1-14 are currently pending in the above-identified application.

Specification

A substitute specification is attached as required by the Examiner.

Abstract

The Abstract has been amended to conform with the specification.

35 U.S.C. §112

The claims have been amended to overcome the outstanding rejection under 35 U.S.C. §112, second paragraph. The Examiner is hereby requested to contact the undersigned by telephone with any questions and to resolve any minor issues that may remain.

35 U.S.C. §103

Claims 1-6 stand rejected under 35 U.S.C. §103(a) as being unpatentable over JP 7-82698. Claims 1, 2 and 6 stand rejected as being unpatentable over JP 1-21557. These rejections are traversed as follows.

According to the presently claimed invention, the magnetic disk apparatus has a lubricant source and a number of components. An inner portion of the magnetic disk apparatus has a temperature that is higher than a base cover or a base thereof when the magnetic disk apparatus is operated. This inner portion is coated with a lubricant having an average molecular weight from 900 to 2500. As discussed on page 6, lines 11-13 of the original specification, the average molecular weight of lubricant applied to a magnetic disk in the prior art was in the range of 3000 to 6000. The present inventors have discovered that using a lubricant having an average molecular weight from 900 to 2500 is advantageous and is efficiently supplied to inner portions of the magnetic disk apparatus utilizing heat generated by operation of the apparatus.

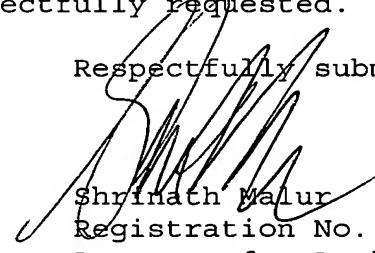
None of the prior art references disclose this range of average molecular weight for the lubricant. It is submitted that the results illustrated in table 2 would not have been

obvious to one of ordinary skill in the art absent hindsight reasoning. This is also true for the results shown in Fig. 2. JP 7-82698 and JP 1-21557 do not disclose the claimed features of the present invention. In addition, the reference cited of interest to Gregory et al actually teaches away from the presently claimed invention by stating that the lubricant source should be mounted at the coolest temperature location within the disk file (see column 8, lines 20-28). As such, it is submitted that the pending claims patentably define the present invention over the cited art.

Conclusion

In view of the foregoing amendments and remarks, Applicants contend that the above-identified application is now in condition for allowance. Accordingly, reconsideration and reexamination are respectfully requested.

Respectfully submitted,


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Title of the Invention

MAGNETIC DISC APPARATUS AND ITS FABRICATING METHOD

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SPECIFICATION

TITLE OF THE INVENTION

MAGNETIC DISC APPARATUS AND ITS FABRICATING METHOD

5

BACKGROUND OF THE INVENTION

Field of the Invention

The present invention relates to a magnetic disc apparatus using a lubricant supply head-disc interface
10 method of supplying that supplies lubricant to a magnetic disc platter from a specific lubricant supply source. Particularly, it relates to a lubricant whose average molecular weight measures in a specific range in order to obtain high reliability for a long period of time using inner portions of the apparatus as
15 a lubricant supply source. It also relates to a fabricating method of the apparatus having the lubricant a magnetic disc apparatus the high reliability of which is secured for a long term using a component
20 in apparatus to which lubricant having average molecular weight in a specific range is applied as a lubricant supply source and its fabricating method.

Description of the Related Art

25 A technique for supplying lubricant to a magnetic disc platter in a magnetic disc apparatus and a technique for specially arranging a lubricant supply mechanism for supplying lubricant utilizing hot air in an apparatus on a base under a spindle is disclosed in

Japanese published examined patent application No. Hei 1-21557. In such at this case, as the structure of the magnetic disc apparatus becomes complex and the a method of assembling the apparatus isbecomes more complex, 5 thereby increasinginge of the cost and the deterioratingion ef productivity become a problem.

A magnetic disc apparatus characterized in that lubricant ofin the same group as lubricant applied to a magnetic disc is applied to a bearing of an actuator, a 10 guide rail or a bolt fastened part is also proposed in Japanese published examined patent application No. Hei 7-82698. Recently, with respect tofor lubricants applied on a magnetic disc, fluoric lubricant having an end functional group is used and is very expensive. 15 When lubricant in the same group as lubricant applied to a magnetic disc is used for a mechanically worn part in a magnetic disc apparatus, a large quantity of lubricant is required and the increase ef thein cost isbecomes unavoidable.

20 Also, in the above-mentioned two prior art references, the molecular weight of the lubricant, which is the most important forwhen considering a lubricant supply method, is not defined. Therefore, 25 these references do not sufficiently disclose how to adequately and the prior arts are insufficient to secure high reliability, which is the of utmost importancet asfor a magnetic disc apparatus for ain the long term.

SUMMARY OF THE INVENTION

Ordinarily, the quantity of lubricant on a magnetic disc decreases together with the increase in 5 operation hours of an apparatus. For the The main reasons, are the shearing force of air generated by the rotation of the magnetic disc, the scatter by due to centrifugal force, evaporation due to the rise of temperature in an apparatus and being scratched by a- 10 touch to contact with a magnetic head can be given. For the role of lubricant on the magnetic disc, it is needless to say to avoid the crush due to a direct touch to the magnetic head, however, as the lubricant reduces surface energy on the magnetic disc and 15 possibly prevents a contamination in the apparatus from being absorbed, the stable flying of the magnetic head can be maintained. As the above-mentioned action of the lubricant is impaired when the lubricant having such a role decreases, reliability for storing data 20 which is the most important as for a magnetic disc apparatus is lost and it is a large problem.

In the meantime Meanwhile, the working conditions of a magnetic disc apparatus vary are various. 25 Particularly, a magnetic disc apparatus used in a portable terminal such as a notebook-sized personal computer is frequently turned on/off. As Under such a working condition, the temperature inside the apparatus does not enough rise enough and lubricant hardly

evaporates. Therefore, high reliability cannot be acquired in the above-mentioned prior arts references. Also, there is a problem that failure is high in the beginning of operation even in a magnetic disc apparatus normally operated such as a magnetic disc apparatus mounted in RAID and a server and reliability against wearing before the temperature inside the apparatus rises is required to be secured.

5 Further, a magnetic disc apparatus is required to maintain initial performance for a long term. Thusen, the magnetic disc apparatus is required to have a lubricant supply function for also supplying enough lubricant when time to some extent elapses.

10 To achieve the above-mentioned objects, the reduction of the cost and simple assembling means without complex structure are required to be realized.

15 The invention is made to solve the above-mentioned problems and the object is to provide a magnetic disc apparatus that can maintain initial performance for a long term since the beginning of the 20 operation at a low cost.

25 To achieve this object, in the magnetic disc apparatus according to the invention having a system of supplying lubricant to a magnetic disc platter, at least any of the components in apparatus components in the apparatus whose temperature, while the magnetic disc apparatus is operated, of which is higher than the temperature of a cover or a base of the magnetic disc

apparatus is coated with lubricant. The -the number
average molecular weight of whichthe lubricant is in a
range of 900 to 2500.

Further, it is desirable that the temperature
5 while the magnetic disc apparatus is operated of the
~~component in apparatus~~component in the apparatus coated
with the lubricant is higher than the temperature of
the cover or the base of the magnetic disc apparatus by
10 C° or more.

10 Also, the surface of a read/write IC unit and the
surface of a magnet of a voice coil motor (VCM) in the
magnetic disc apparatus are coated with lubricant of
low average molecular weight.

Furthermore, at least any of the surfaces
15 substantially perpendicular to the data surface of the
magnetic disc platter of components located outside the
magnetic disc platter when it is viewed from the
rotational center in the magnetic disc apparatus is
coated with lubricant ~~for supply~~.

20 Also, the cover, the base, a pivot bearing and a
tapped hole for screwing a spindle and others in the
magnetic disc apparatus are coated with lubricant.

Further, the coated lubricant is
perfluoropolyether lubricant shown in the following
25 chemical formula (1).

$\text{CH}_2\text{OH}-\text{CF}_2(\text{OCF}_2\text{CF}_2)_m-(\text{OCF}_2)_n-\text{CH}_2\text{OH}$ (m and n=
integer being natural numbers) --- Chemical formula (1)

Further, in a fabricating method of the magnetic

disc apparatus of the system of supplying lubricant to the magnetic disc platter in the magnetic disc apparatus, a process for coating a ~~component~~ components in the magnetic disc apparatus which is a supply source of lubricant with lubricant includes at least any of a lubricant dip coating process, a coating process using a brush and a sponge marker and a process for dropping lubricant via a tapped hole for attaching the cover of the magnetic disc apparatus to the base.

10

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a schematic drawing showing a magnetic disc apparatus;

15

Fig. 2 shows relation between the surface temperature of ~~components~~ components in the magnetic disc apparatus to which lubricant for supply according to the invention is applied and the quantity of lubricant supplied to a magnetic disc platter; and

20

Fig. 3 shows the comparison of time required to supply lubricant for supply according to the invention to the magnetic disc platter.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

25

The invention will be described based upon its embodiments below. Ordinarily, the ~~number~~-average molecular weight of lubricant applied on a magnetic disc is in a range of 3000 to 6000. Lubricant used in the invention for applying on a magnetic disc is

perfluoropolyether lubricant having a hydroxyl group at both ends and shown in the expression (1) and the number-average molecular weight is 32000. In the invention, for lubricant applied on a magnetic disc platter, the above-mentioned lubricant is also used.

For lubricant applied to a ~~component in magnetic disc apparatus~~ component in the magnetic disc apparatus for supplying onto a magnetic disc, that is, lubricant used for supply, as a result of the examination of how efficiently the lubricant is supplied in the invention, it was found that the lower the molecular weight of the lubricant was, the more easily the lubricant was supplied and lubricant the average molecular weight of which was in a range of 900 to 2500 was suitable for lubricant ~~for to be supply~~.

In the following embodiments, examples that lubricant having clearly lower molecular weight (number average molecular weight: approximately 2000), compared with that of lubricant applied on a magnetic disc beforehand and shown in the expression (1) is used for lubricant for supply are shown. This lubricant is perfluoropolyether having a hydroxyl group at both ends. For a solvent of lubricant, Nobeck HFE7100 manufactured by 3M is used. In the embodiments, lubricant having a hydroxyl group at the end is used, however, if lubricant the end group shown in the expression (1) of which has polarity is used, the similar effect can be acquired.

Fig. 1 shows the structure of a magnetic disc apparatus used in the embodiments and an example for comparison.

A magnetic disc 105 is attached to a spindle on a base 101 via a spacer and by a cap 104. A magnetic head 106 is attached to a voice coil motor (VCM) formed by a head assembly 111 including a magnet 109 and a coil via an arm and is built on the base. The head is positioned with a pivot bearing 107 in the center.

10 A read/write signal to the magnetic head is processed via read/write IC 108. Recently, a ramp 110 for backing the head as a loading/unloading mechanism is also attached to the base. A filter 103 is provided to clean the inside of the magnetic disc apparatus.

15 After these components are built, the base is covered with a base cover 102 and is sealed.

(Embodiment 1)

A magnetic disc apparatus shown in Fig. 1 was operated at the ambient temperature of 24 C° and the 20 temperature of each component in the apparatus when the elapse of five hours elapsed was measured using a thermocouple (Table 1). The operation of the apparatus was performed by the repeating read and write at random seek with the rotational speed of a magnetic disc being 25 4200 min⁻¹ and with the floating height of a head being approximately 10 nm.

According to the result shown in Table 1, it is known in the comparison in surface temperature of each

component after five hours from the initiation of the operation that the temperature of read/write IC and a magnet of VCM is higher than that of a base by 10 C° or more.

5

Table 1

Operation hours [h]	Component-in-apparatus surface temperature [□]		
	Read/Write IC	VCM magnet	Base
0	23.3	23.1	23.2
5	50.1	42.5	30.8

To know the effect of lubricant supply to the magnetic disc platter from lubricant applied to a component-in-disk-apparatus component in the disc apparatus, total three magnetic disc apparatuses in which the above-mentioned lubricant for supply was applied to any of the surface of the read/write IC, the surface of the VCM magnet and the base (in the vicinity of the read/write IC) which were respectively a component-in-magnetic-disc-apparatus were prepared. The application of lubricant was performed by applying 5 wt% solution of lubricant using a sponge marker manually. At this time, no lubricant was applied to the magnetic disc platter mounted in the magnetic disc apparatus.

The operation of the three magnetic disc apparatuses was performed by repeating read and write at random seek with the rotational speed of the magnetic disc 4200 min^{-1} and with the floating height of the head approximately 10 nm for five hours.

The magnetic disc platter was extracted from the magnetic disc apparatus after the operation on the above-mentioned condition and the thickness of lubricant was measured as the quantity of lubricant 5 supplied to the magnetic disc platter. Fig. 2 shows the result together with the component surface temperature shown above.

It is known that from this result that the supply quantity to the magnetic disc platter in case lubricant 10 for supply is applied to the VCM magnet and the read/write IC is extremely more than the supply quantity in case lubricant for supply is applied to the base. Needless to say, it is obvious that in the case of a conventional type in which no lubricant for supply 15 is applied to a ~~component in magnetic disc apparatus~~
~~component in the magnetic disc apparatus~~, there is no possibility of such lubricant supply.

The result shows that lubricant can be efficiently supplied to the magnetic disc platter while 20 the apparatus is operated by applying lubricant ~~for supply to the components the whose temperature of which becomes higher than that of the base out of components in magnetic disc apparatus.~~

The thickness of lubricant on the magnetic disc 25 platter was measured by a Fourier transform infrared spectrophotometer (FTIR).

The magnetic disc apparatus shown in Fig. 1 was operated on the above-mentioned condition for 1000

hours in a state that lubricant for supply was applied on the surface of the read/write IC, however, it was verified that no problem was caused in a reading/writing system and a driving system.

5 It is judged based upon the result of this embodiment that if lubricant for supply is applied to a component in the magnetic disc apparatus the surface temperature of which becomes higher than that of the base except the VCM magnet and the read/write IC in operation, the similar effect by high temperature can be acquired. Particularly, in case the surface temperature becomes higher by 10 C° or more, the effect is remarkable.

10 (Embodiment 2)

15 A magnetic disc apparatus in which the above-mentioned lubricant for supply was applied to a shroud (a component located outside a magnetic disc platter when it was viewed from the rotational center and an external wall of the base having the surface perpendicular to the data surface of the magnetic disc platter) of a base which was a component in the magnetic disc apparatus was prepared. The lubricant for supply was applied as in the embodiment 1. No lubricant was applied to the magnetic disc platter mounted in the magnetic disc apparatus.

20 This magnetic disc apparatus was operated for five hours in a state that read and write at random

seek were repeated with the rotational speed of the magnetic disc 4200 min^{-1} and with the floating height of a head approximately 10 nm.

The result of extracting the magnetic disc
5 platter from the magnetic disc apparatus after the
operation on the above-mentioned condition and
measuring the thickness of the lubricant supplied on
the magnetic disc platter as the supplied quantity was
0.5 nm. It is known from the result that in this
10 embodiment, the supply of lubricant to the magnetic
disc platter is also achieved in the operation of the
apparatus in short time. It is conceivable that as air
flows fastest in the apparatus in the vicinity of the
outer end of the magnetic disc platter, lubricant for
15 supply easily evaporates and is efficiently supplied.

In the magnetic disc apparatus shown in Fig. 1,
lubricant for supply was applied to the shroud of the
base and the magnetic disc apparatus was operated on
the above-mentioned condition for 1000 hours, however,
20 it was verified that no problem was caused in a
reading/writing system and a driving system.

The similar effect can be also acquired by the
application of lubricant for supply to a component
having the surface perpendicular to the data surface of
25 the magnetic disc platter out of components located
outside the magnetic disc platter when it is viewed
from the rotational center such as a block E (described
on a page 10 of "Advanced storage terminology

dictionary" published in Apr. in 2000 and by Nikkei BP) in the apparatus.

(Embodiment 3)

An apparatus was assembled after the solution of lubricant for supply described in the embodiment 1 was manually applied to the surface corresponding to the position of VCM of the cover of the magnetic disc apparatus shown in Fig. 1 using a small brush, a pen and a sponge marker. Also, after the solution was manually applied to a position in which VCM was attached on the base of the apparatus after a stick for cleaning of a type that hardly stirred up dust made of polyurethane was dipped in the solution, the apparatus was assembled. The application of the lubricant for supply was performed in a state in which only a spindle is attached on the base. That is, the application of the lubricant for supply in this embodiment to components in the apparatus can be performed during a normal magnetic disc assembling process and the change of the design of the magnetic disc apparatus is not required. The time required for applying the lubricant for supply is a short time, within a few seconds per one apparatus, and the production efficiency of the magnetic disc assembling process is not sacrificed.

A magnetic disc apparatus in which no lubricant for supply was applied to the above-mentioned components was prepared for an example for comparison 1.

In this embodiment, a magnetic disc platter to which lubricant shown in the chemical formula (1) and having the average molecular weight of 32000 is applied by 2.0 nm is mounted in the magnetic disc apparatus.

5 After the magnetic disc apparatuses respectively produced for this embodiment and the example for comparison 1 were operated at 70 C° for 1000 hours, the thickness of the lubricant on the magnetic disc platters and the contamination of heads were compared.

10 Table 2 shows the result. The rotational speed of the operated magnetic discs was 4200 min^{-1} and the floating height of the heads was approximately 10 nm. The contamination of the heads was observed using a optical microscope. Table 2 also shows the result.

Table 2

	Supply lubricant coated location/Method	Result after test	
		Lubricant thickness	Head contamination
Embodiment 3	Cover (VCM surface)/Application by small brush	2.1 nm	None
	Cover (VCM surface)/Application by pen	2.0 nm	None
	Cover (VCM surface)/Application by sponge marker	2.0 nm	None
	Cover (VCM attachment)/Application by stick	1.9 nm	None
Embodiment 4	Ramp tapped hole/Microdispenser Pivot bearing fixing hole/Microdispenser	1.8 nm 2.1 nm	None None
Example for comparison 1	No supply lubricant	1.3 nm	Found

In any case of the embodiment 3, it is known that
 the thickness of a lubricant film (2.0 nm) on the
 5 magnetic disc platter before the operation is
 substantially maintained. The contamination of the
 heads was not recognized. In the meantime, in the
 example for comparison 1, the thickness of a
 lubrication film on the magnetic disc platter was 1.3
 10 nm, decreased than the thickness before the operation
 by 0.7 nm and the contamination of the head was
 recognized.

From the above-mentioned result, it can be
 concluded that the magnetic disc apparatus equivalent
 15 to this embodiment is excellent in maintaining the
 reliability in the long-term operation, compared with
 the magnetic disc apparatus to a component of which no
 lubricant for supply is applied in the example for

comparison 1.

For a method of applying lubricant for supply, if a method of application such as application by a hand spray and a disperser can be realized at a low price, 5 the similar effect can be acquired.

(Embodiment 4)

As a embodiment 4, a magnetic disc apparatus shown in Fig. 1 in which lubricant for supply was injected into a tapped hole 113 for attaching a ramp 10 after the component was attached to a base, was injected into a tapped hole for fixing a pivot bearing of VCM in a state in which the base is sealed with a cover and afterward, a screw was driven was prepared. The injection of the lubricant for supply was performed 15 by dropping the 50 wt% solution of the lubricant for supply into a 2-microliter tapped hole using a microdispenser.

In this embodiment, as in the embodiment 3, a magnetic disc platter to which lubricant shown in the 20 chemical formula (1) and having the average molecular weight of 32000 was applied by 2.0 nm was mounted in the apparatus.

After the apparatus was operated on the similar operational condition to that in the embodiment 3, the 25 thickness of a lubricant film on the magnetic disc platter and the contamination of a head were observed. The result shows that the thickness of the lubricant film is substantially maintained as in the embodiment 3

as shown in Table 2 and it was verified that the contamination of the head was not recognized.

After lubricant for supply was further manually applied to a VCM mounting position on the base of the 5 magnetic disc apparatus shown in Fig. 1 using a small brush, a pen and a sponge marker, the apparatus was assembled.

(Embodiment 5)

An apparatus (an embodiment 5-1) in which 10 lubricant for supply was manually applied to VCM based upon the magnetic disc apparatus shown in Fig. 1 and an apparatus (an embodiment 5-2) in which lubricant for supply was injected into a tapped hole for attaching a ramp as in the embodiment 4 based upon the magnetic 15 disc apparatus shown in Fig. 1 were prepared.

After the apparatuses were operated on the similar operational condition to that in the third embodiment, a magnetic disc platter to which no lubricant was applied was respectively built and 20 mounted in the magnetic disc apparatuses every elapse up to 1000 hours and the apparatuses were operated for 24 hours, the magnetic disc platters were removed and the thickness of a lubricant film on the magnetic disc platter was respectively measured. Fig. 3 shows the 25 result.

It is known from Fig. 3 that in the embodiment 5-2, timing in which lubricant for supply starts to be supplied and adhere to the magnetic disc platter is

later than timing in the embodiment 5-1 and there is delay effect in the supply of lubricant. If delay effects are combined, they are particularly effective in the supply of lubricant in the magnetic disc apparatus requiring long-term apparatus life.

That is, according to the invention, further, in the magnetic disc apparatus provided with a mechanism for supplying lubricant in a state of gas in the magnetic disc apparatus, even if environmental temperature inside the apparatus does not rise, lubricant can be efficiently evaporated by dropping or applying lubricant to a component the temperature while the apparatus is operated of which becomes higher than the temperature of the cover out of components located in the magnetic disc apparatus, concretely to a component in which electric resistance is generated by electrical conduction while the apparatus is operated and the temperature of which inductively rises such as the read/write IC, the voice coil motor (VCM) and further, the periphery of the spindle and can be supplied to the magnetic disc platter or an interface between a head and the disc.

Also, even if environmental temperature in the apparatus does not rise, lubricant can be efficiently evaporated by dropping or applying lubricant to a component located in the vicinity of the outer end of the magnetic disc where relative velocity with air is the fastest in the magnetic disc apparatus and can be

supplied to the magnetic disc platter or the interface between the head and the disc.

According to the invention, the low-priced magnetic disc apparatus can be acquired without 5 specially providing a lubricant supply mechanism. The apparatus can be also easily assembled. Further, lubricant can be efficiently supplied from the beginning of the operation of the apparatus. Therefore, the magnetic disc apparatus the reliability of which is 10 high can be provided.